Crop Growth as Affected by Bio-energy Byproducts Application

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Abstract

This study aimed to examine the effect of bio-energy byproducts (BEB) when applied directly or indirectly through manure production on crop yield. It consisted of three field experiments. The first experiment investigated the effect of manure derived from wet distillers grain compared to barley manure on wheat yield, the second experiment investigated the effect of thin stillage versus urea application on wheat yield, and the third investigated the effect of wet distillers grain, biochar applied alone or combined with urea, and glycerol applied alone or combined with urea on canola yield. Yields with WDG-fed versus barley-fed cattle manure were similar, in line with similar composition that was found for the two manure sources. Per unit of N added, the thin stillage produced equivalent or higher yields than urea. This is explained by other nutrients in thin stillage, including phosphorus, that would contribute to plant nutrition and yield. Pure or high carbon content amendments (GL, BC) had limited effect on yield when applied alone. Bio-energy processing byproducts can be effective amendments to provide carbon and nutrients to the soil and plants.

Introduction

Increased bio-energy production has been associated with a large amount of bio-energy processing byproducts (BPB). These byproducts include but are not limited to: wet distillers grain (WDG) and thin stillage (TS) from ethanol production; glycerol (GL) which is generated during biodiesel production; and biochar (BC) generated from pyrolysis processes. Some of the BPB have uses as animal feed or energy production feedstocks themselves.

Distillers grain is commonly used as animal feed, and thin stillage can be used as a partial or complete replacement of drinking water for cattle (Mustafa et al., 2000). When distillers grain is fed to animals, it will have a significant influence on animal manure composition (Hao et al., 2009). Glycerol surpluses may be incinerated (Glycerol Challenge, 2007). Biochars and ashes arise from pyrolysis and gasification processes of many different organic materials. In addition to other uses, BPB may have benefit in use as soil organic amendments. Therefore, the objective of this study was to investigate the effect of WDG wheat and barley fed ration manure compared to barley fed manure broadcast and incorporated or injected in the fall on crop growth during subsequent growing season and to investigate the effect of direct application of BPB on crop production.

Materials and methods

To address the research objectives, three field experiments were conducted.

Experiment 1

Wet Distillers Grain Fed Cattle Manure (WDGFCM) versus Barley Fed Cattle Manure (BFCM)

The experimental site is located in east-central Saskatchewan, Canada, near the town of Dixon. The predominant soil at the site is classified as Black Chernozems (Cudworth Association) with clay texture. The field experiment was designed to include 10 treatments: two types of cattle manures, and each type was applied at two rates using two methods of application (injected or broadcasted and incorporated). Disturbed and undisturbed checks were also included as a control. As detailed, the 10 experimental treatments were: wet distillers grains fed cattle manure (WDGCM) broadcast and incorporated or injected at a rate of 15 or 30 tonnes ha-1, barley fed cattle manure (BCM) broadcast and incorporated or injected at a rate of 15 or 30 tonnes ha-1; disturbed or undisturbed control. The experimental design was a randomized complete block with four replicates. The plots dimensions were 3 m width × 6 m length. Field was cropped to wheat in May 2009. Plants were harvested when physiological maturity was reached. Tow 1-m^2 plant samples per plot will be cut manually above the surface. The samples will be dried by forced air at 45 °C, total biomass weighed, and mechanically threshed using a stationary thresher. Then, grain and straw yield was determined.

Experiment 2

Direct Application of Thin Stillage (TS) versus Urea

The experimental site is located in east-central Saskatchewan, Canada, near the town of Dixon. The predominant soil at the site is classified as Black Chernozems (Cudworth Association) with clay texture. The field experiment was designed to include 11 treatments: three rates of thin stillage injected or broadcasted and three rates of urea. Disturbed and undisturbed checks were also included as a control. As detailed, the 11 experimental treatments were: thin stillage was applied at three rates, 16800, 33600 or 67200 L/ha using two methods of application (injection or broadcast) for each rate and mineral fertilizer was applied at three urea-N rates, 50, 100 or 200 kg N/ha; disturbed or undisturbed control. The three rates of thin stillage of 16800, 33600 or 67200 L/ha will provide approximately 50, 100 or 200 kg N/ha respectively, assuming that about 60% of thin stillage-total N will be available, and this will be appropriately comparable to the three rates of totally available urea-N (50, 100 or 200 kg N/ha). The experimental design was a randomized complete block with four replicates. The plots dimensions were 3 m width × 9 m length. Plants were harvested when physiological maturity was reached. Tow 1-m^2 plant samples per plot will be cut manually above the surface. The samples will be dried by forced air at 45 °C, total biomass weighed, and mechanically threshed using a stationary thresher. Then, grain and straw yield was determined.

Experiment 3

Direct Application of WDG, GL and BC

The experiment was initiated in the spring of 2009 at a private farm located near the town of Central Butte, southwestern Saskatchewan, Canada. The soil at the experimental site was classified as Orthic Brown Chernozem (Soil Association: Ardill Loam), with a loamy texture. The experimental plots dimensions were 2 × 2 m^2. The field experiment was designed to include 7 treatments which are: a rate of 2000 kg C/ha of glycerol applied alone or combined with 100 kg N/ha as urea, one rate of biochar (2000 kg C/ha) applied alone or combined with 100 kg N/ha as urea, one rate of wet distillers grain (100 kg N/ha) applied alone, and one rate of urea applied at 100 kg N/ha and a plot received no treatment was a control. The experiment was set up in a randomized complete block design with four replicates. Field was seeded to canola. Plants were harvested when physiological maturity was reached. 1-m^2 plant samples per plot were cut manually above the surface. The samples were dried by forced air at 45 °C, total biomass weighed, and mechanically threshed using a stationary thresher. Then, seed and straw yield was determined.

Results and Discussion

Effect of WDGFCM and BFCM on wheat grain yield

Manure addition significantly increased wheat grain yield (Fig. 1), with highest grain yield at the high rate (30 tonnes ha^{-1}). A slightly better yield response is observed when manure was injected. Yields with WDG - fed versus barley - fed cattle manure were similar, in line with similar composition that was found for the two manure sources. Per unit of nutrient added, there would appear to be relatively little difference in yield responses of crop to the two different manure sources.

Effect of TS versus Urea on Wheat Grain Yield

All treatments significantly increased the yield, compared to the unfertilized control (Fig. 2). Injected thin stillage resulted in higher grain yields than broadcast thin stillage at low and medium rates. This may be due to additional volatilization losses of ammonium when TS is surface applied. Per unit of N added, the thin stillage produced equivalent or higher yields than urea. This is explained by other nutrients in thin stillage, including phosphorus, that would contribute to plant nutrition and yield. Injection of thin stillage appears to be an effective strategy for supplying nutrients to crops, similar to liquid manure injection.

Effect of WDG, GL and BC on Canola Yield

Pure or high carbon content amendments (GL, BC) had limited effect on yield when applied alone (Fig.3). Biochar plus urea showed equivalent or greater yield than other treatments, despite having only half as much urea N added, suggesting that biochar may be improving nutrient retention and utilization. Wet distillers grain was an effective amendment, supplying N and other nutrients like P and S.

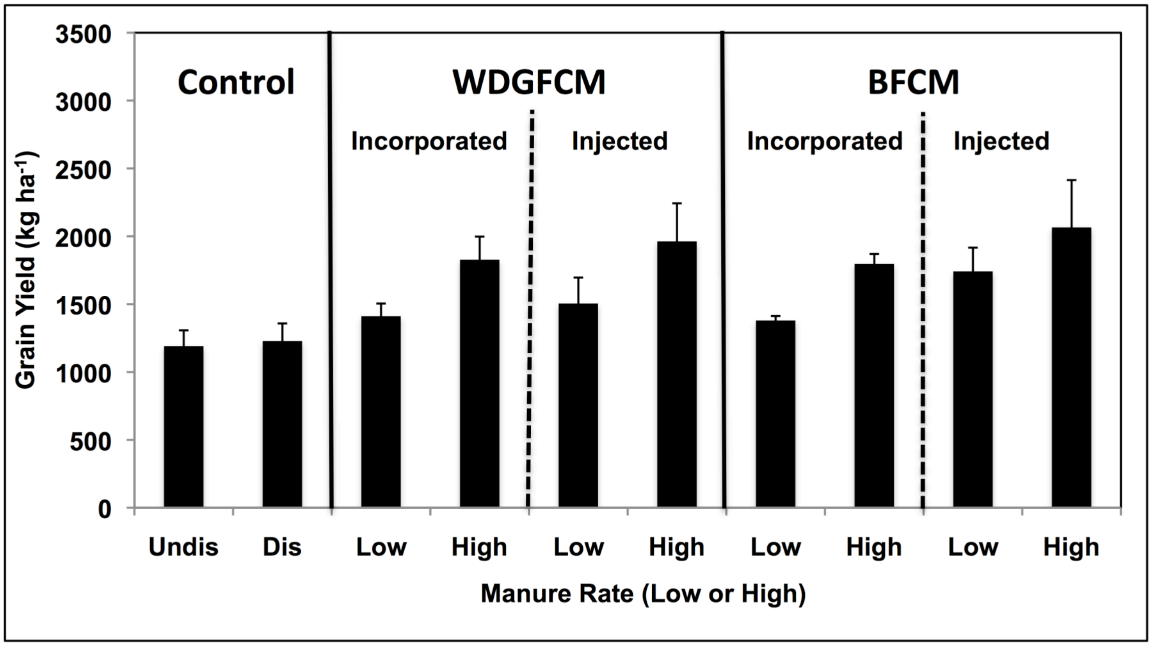

Figure 1. Effect of wet distillers grain fed cattle manure (WDGFCM) and barley fed cattle manure (BFCM) applied at 2 rates (low or high) injected or incorporated on wheat grain yield.

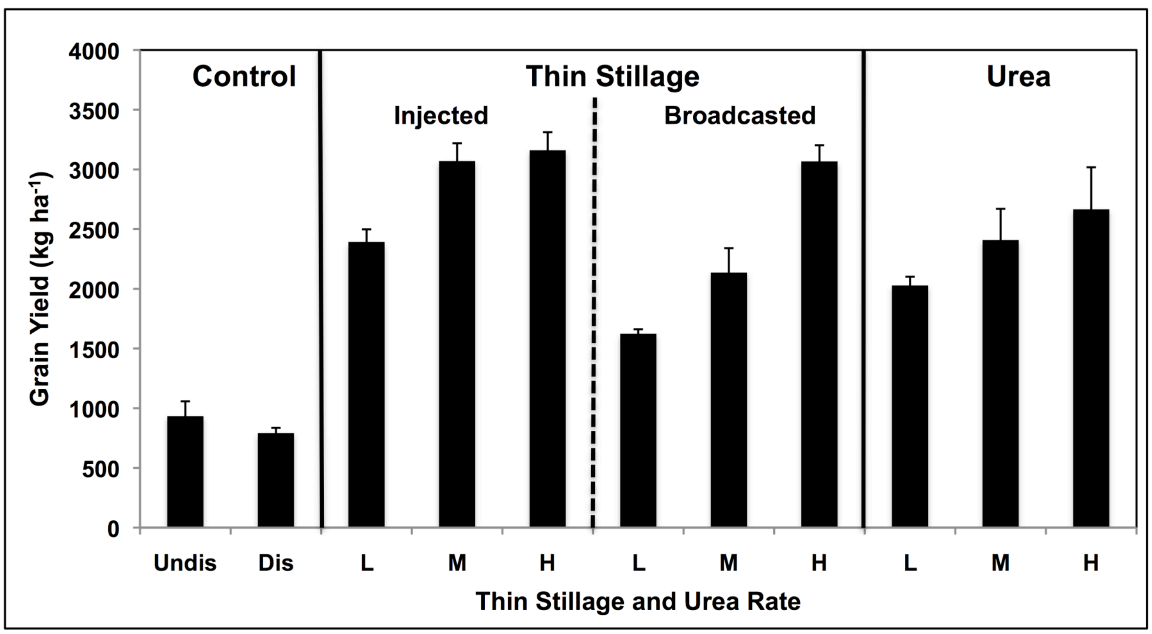

Figure 2. Effect of thin stillage (TS) and urea applied at low (L), medium (M) and high (H) rates on wheat grain yield. Thin stillage was injected or broadcasted. TS and urea were applied in the fall.

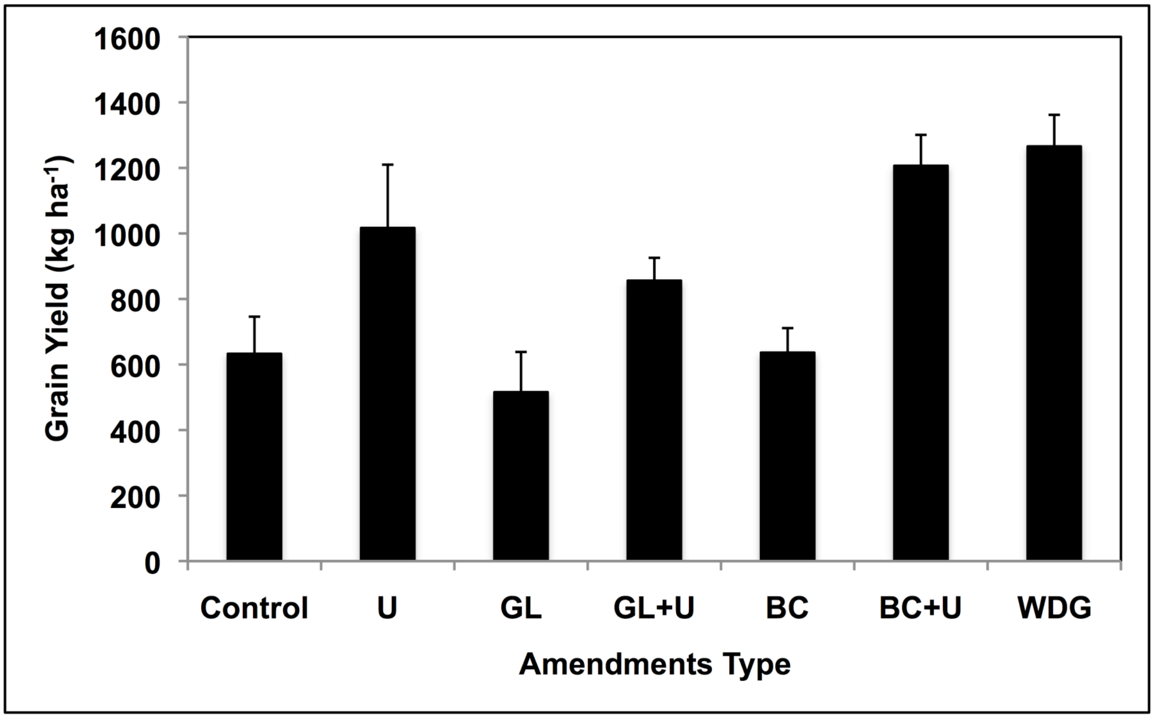

Figure 3. Effect of 100 kg N/ha urea (U), glycerol (GL) applied alone or combined with 100 kg urea-N (GL+U), biochar (BC) applied alone or combined with 50 kg urea-N (BC+U) and wet distillers grain (WDG) applied at 100 kg N/ha on canola seed yield. Amendments were applied before planting time in spring 2009.

Conclusion

Bio-energy processing byproducts can be effective amendments to provide carbon and nutrients to the soil and plants.

Acknowledgement

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